Jack Snoeyink,
UNC Chapel Hill,
Computer Science

Visualization Challenges from Fundamentals

I will focus on some technical challenges, but wish to begin with one philosophical one. From reading other position statements, it seems that visualization research is suffering a crisis of confidence since its successes have been surrounded by equally successful developments of applications that have more influence in the mass market. One challenge for visualization is to continue to adapt to rapidly changing capabilities of generating, storing, processing, and displaying data. It is best to meet such a challenge not by simply reacting to changes, but by understanding the fundamentals of this niche.

A visualization task on a computer, whether it be communicating, educating, or exploring, needs input data, a processing platform, an output device, and a visual story. Most of these are not unique to visualization: Entertainment and business are more important drivers for increasing processor speeds, memory capacities, and graphics performance. Recently, they have even produced large flat-panel and multi-projector displays, at long last increasing the number of pixels and lowering prices. Computational science and engineering experiments and simulations have always provided “fire hoses”[1] of data, albeit sometimes in inconvenient formats or with access restrictions. Many application domains provide visual stories through diagrams and models; e.g., you can read a well-written biology paper by reading the abstract, the figures, and their captions.

The niche of visualization comes in the software aspects of the processing platform – the data structures and algorithms running on the underlying hardware that transform the data into a visual representation that the domain user can understand and manipulate. As someone whose main research is computational geometry, I find my primary challenges among the algorithms and data structures.

- What mathematics can show users the essentials of their data? Applications of Morse theory (Reeb graphs and Contour trees by Shinagawa, Kunii, Bajaj, Edelsbrunner, Pascucci, Carr and others[2]) are attractive in that they can present summaries of characteristics all iso-surfaces in a volume data set. There is active work on extending this to time-varying data as well.

- How can the mathematics be correctly and robustly implemented in a computational algorithm? At a recent visualization workshop at Banff, Herbert Edelsbrunner argued that the discrete nature of the computer means that we should derive and use discrete analogs of continuous theorems, if correct and robust algorithms are important. For example, curvature for a polyhedral surface can be defined by angle sums rather than by smoothing to apply a continuous integral.

- How do we make data representations scale to large data sets? When deriving mathematics or data structures for visualization, it is important to consider how they scale to large data sets. Even simple iso-surfaces become complex when one has to represent cross-references between large lists of triangles and of vertices. Various out of core methods have been proposed,[3] including a streaming representation that makes better use of cache.

- Finally, how can new visualization methods be disseminated in the relevant application domains? Visualization is an area that needs more benchmark data sets and challenges like the graph drawing contest.

---

[1] McCormick. B.H., DeFanti, T.A.. and Brown. M.D.. Eds. Visualization in Scientific Computing. *Computer Graphics,* 21(6), Nov. 1987.

[2] C. L. Bajaj, V. Pascucci and D. R. Schikore. The contour spectrum. In ``Proc. IEEE Conf. Visualization, 1997'', 167--175.
H. Carr, J. Snoeyink and U. Axen. Computing contour trees in all dimensions. *Comput. Geom.* 24(2) (2003), 75--94.
A. T. Fomenko and T. L. Kunii, (eds). *Topological Methods for Visualization.* Springer-Verlag, Tokyo, Japan, 1997.
V. Pascucci and K. Cole-McLaughlin. Efficient computation of the topology of level sets. *Algorithmica*, to appear.
H. Edelsbrunner, J. Harer, A. Mascarenhas, and V. Pascucci. ``Time-varying Contour Trees for Continuous Space-time Data.'' *20th ACM Sympos. on Computational Geometry*, pages 366--372, 2004.

[3] M. Isenburg and P. Lindstrom. Streaming Meshes, manuscript, 2004. http://www.cs.unc.edu/~isenburg/research/papers/il-sm-04.pdf